NAVIER-STOKES SOLUTIONS ABOUT THE F/A-18 FOREBODY-LEX CONFIGURATION

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Abstract

Three-dimensional viscous flow computations are presented for the F/A-18 forebody-LEX geometry. Solutions are obtained from an algorithm for the compressible Navier-Stokes equations which incorporates an upwind-biased, flux-difference-splitting approach along with longitudinally-patched grids. Results are presented for both laminar and fully turbulent flow assumptions and include correlations with wind tunnel as well as flight-test results. A good quantitative agreement for the forebody surface pressure distribution is achieved between the turbulent computations and wind tunnel measurements at $M_\infty = 0.6$. The computed turbulent surface flow patterns on the forebody qualitatively agree well with in-flight surface flow patterns obtained on an F/A-18 aircraft at $M_\infty = 0.34$.

Overview

- Navier-Stokes Formulation
  - CFL-3D
- Grid Generation
  - Transfinite interpolation
- Results
  - Laminar, turbulent flow
  - Comparisons with wind-tunnel experiment
  - Comparisons with flight test
- Summary

Grid Generation - Transfinite interpolation

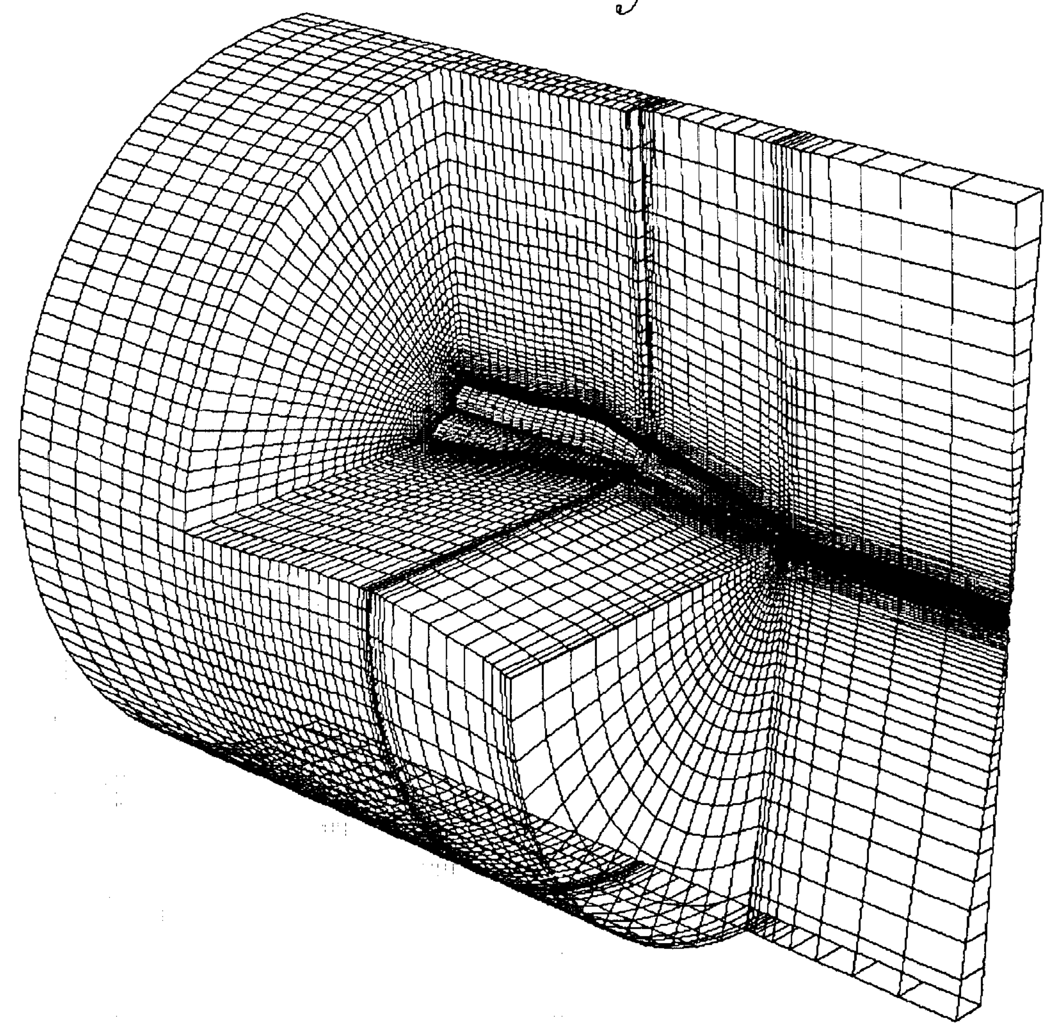
- H-O topology

- Far field
  - Inflow, outflow $\approx 1\ \bar{c}$
  - Radial $\approx 1.5\ \bar{c}$

- Baseline grid
  - Block 1 : $31 \times 65 \times 27$
  - Block 2 : $65 \times 65 \times 31$
  - Approximately 185,000 points
  - $y^+ \approx 2$ for wind-tunnel conditions
  - $y^+ \approx 8$ for flight conditions

- Refined grid
  - Doubled number of radial points
  - Normal surface spacing $\approx 0.25\times$ baseline
  - $y^+ \approx 3$ for flight conditions

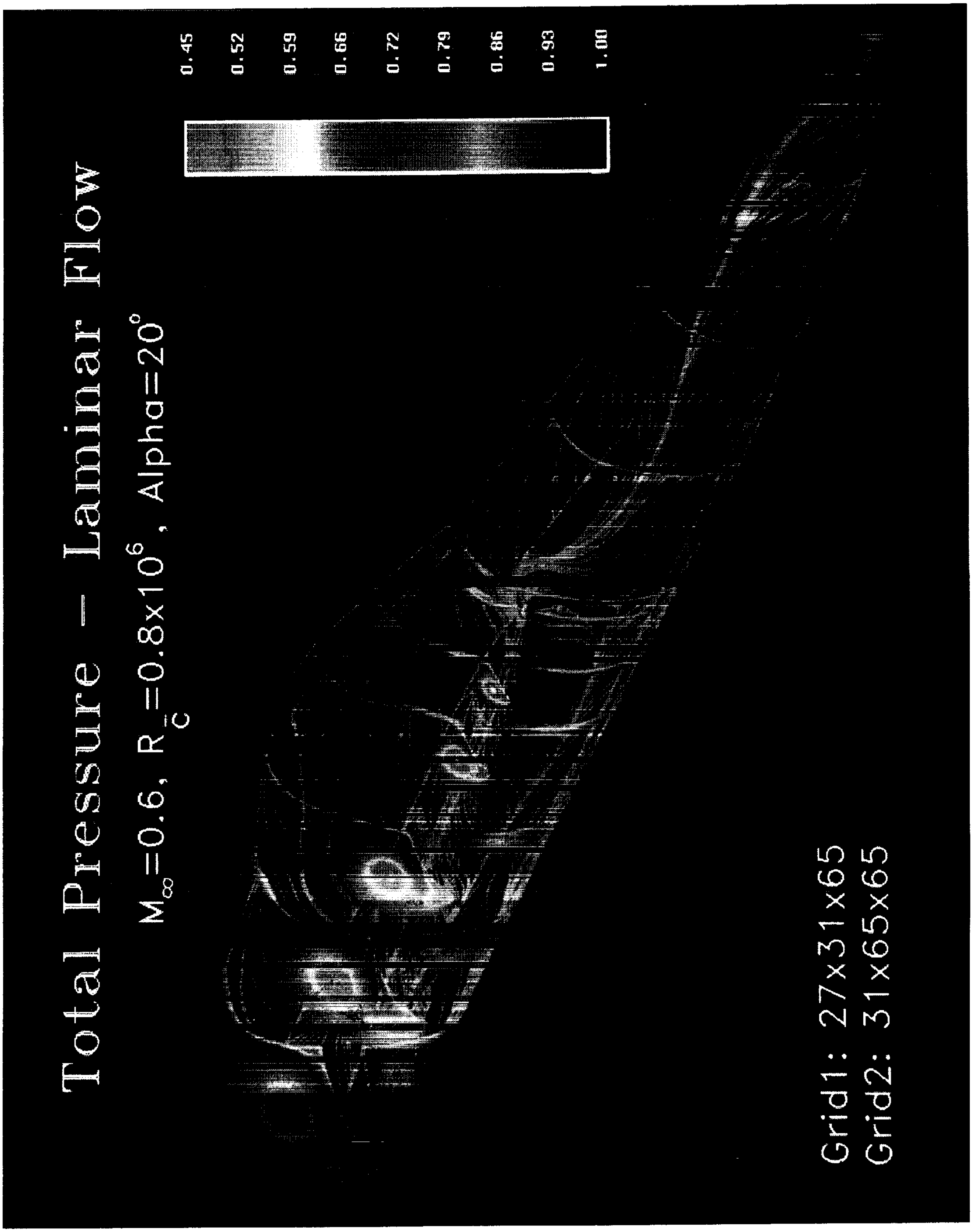
F-18 Forebody-LEX Grid

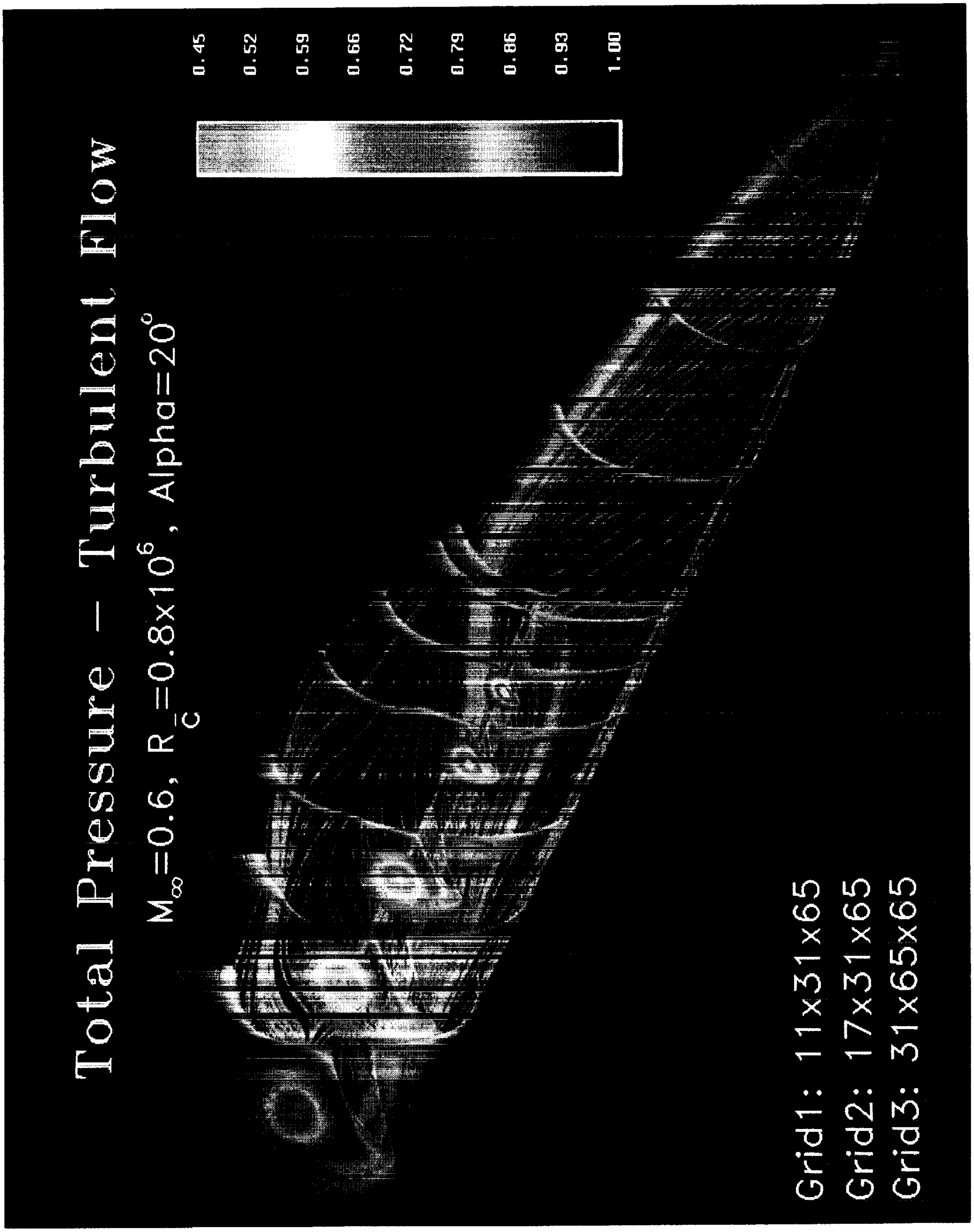


Computed Results

- Wind tunnel conditions
  - $M_\infty = 0.6,\ R_{\bar{c}} = 0.8 \times 10^6,\ \alpha = 20^\circ$
  - Laminar, turbulent flow
  - Comparison with experiment

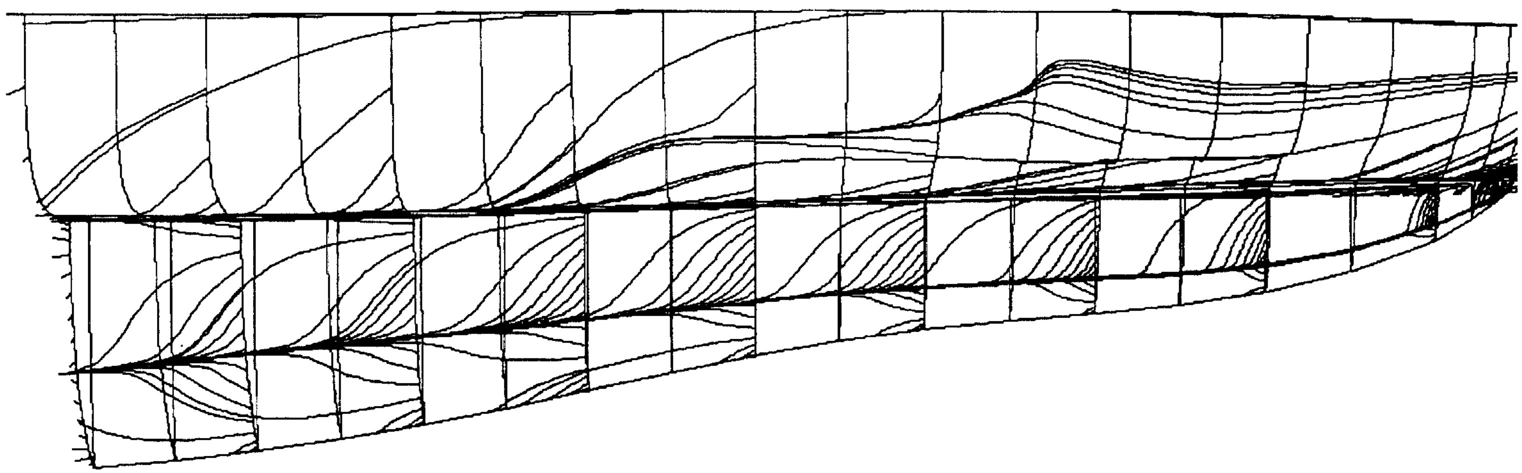
- Flight conditions
  - $M_\infty = 0.34,\ R_{\bar{c}} = 13.5 \times 10^6,\ \alpha = 19^\circ$
  - Turbulent flow
  - Comparison with experiment


Total Pressure – Laminar Flow
$M_\infty=0.6$, $R_{\bar{c}}=0.8\times10^6$, Alpha=20°
0.45
0.52
0.59
0.66
0.72
0.79
0.86
0.93
1.00
Grid1: 27x31x65
Grid2: 31x65x65


Total Pressure - Turbulent Flow
M_∞=0.6, R_c=0.8x10^6, Alpha=20^o
0.45
0.52
0.59
0.66
0.72
0.79
0.86
0.93
1.00
Grid1: 11x31x65
Grid2: 17x31x65
Grid3: 31x65x65

LEX Upper Surface Flow – Laminar

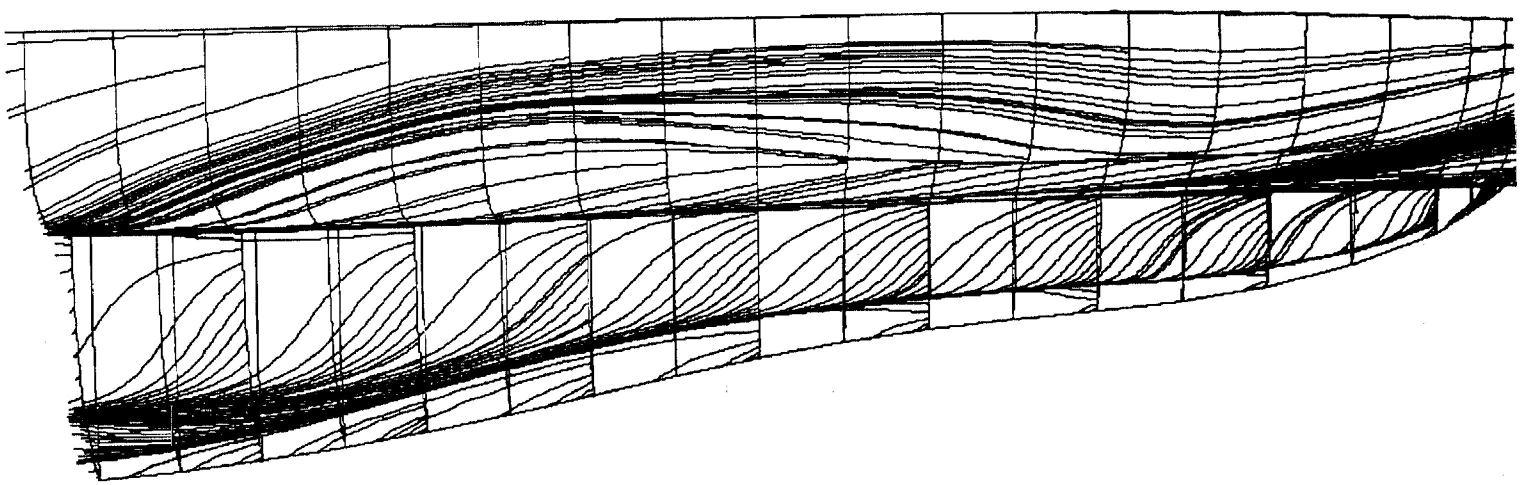
$M_\infty=0.6$, $R_{\bar{c}}=0.8\times10^6$, Alpha$=20^\circ$



Grid1: 27x31x65
Grid2: 31x65x65

LEX Upper Surface Flow - Turbulent

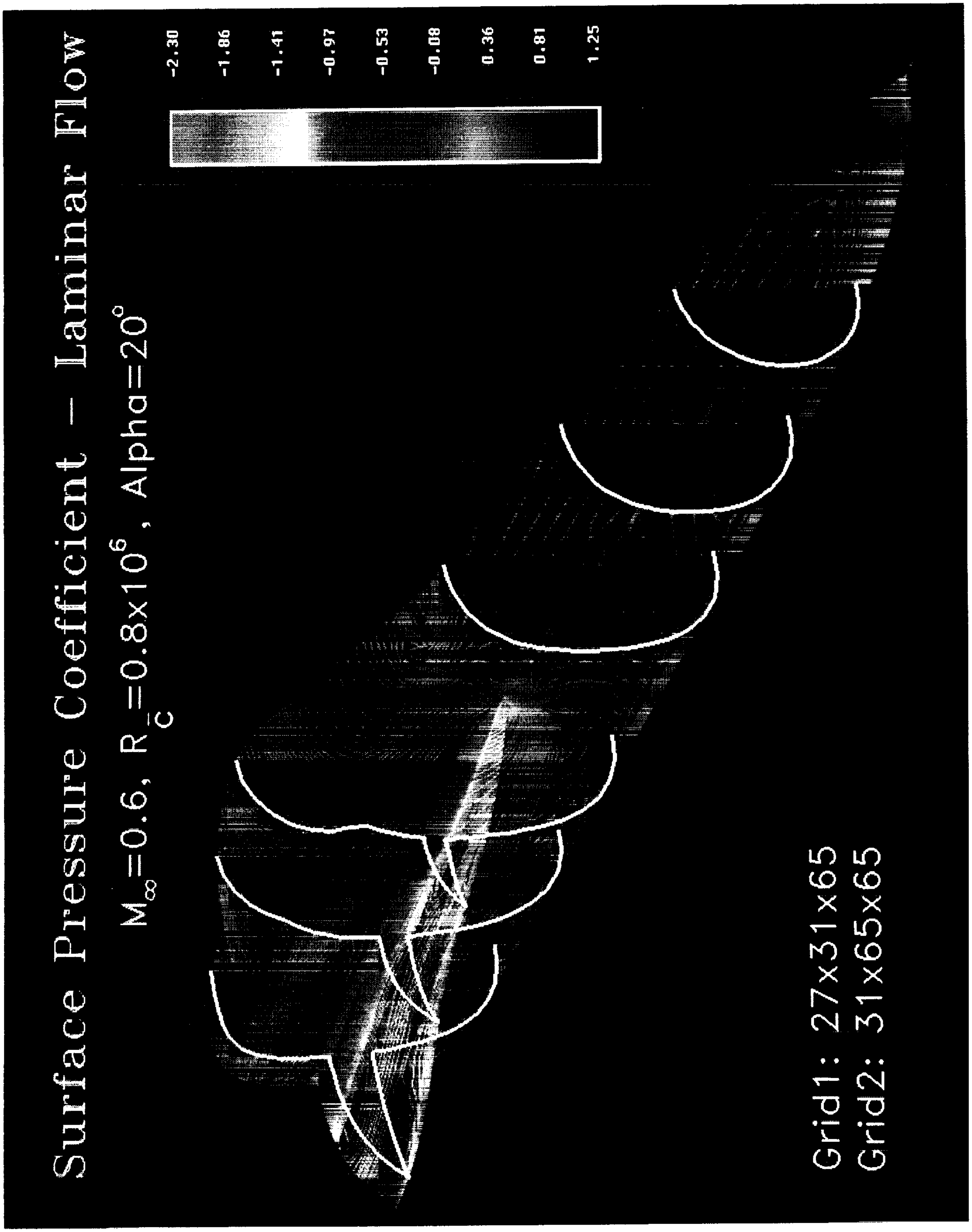
M_∞=0.6, $R_{\bar{c}}$=0.8x10^6, Alpha=20°

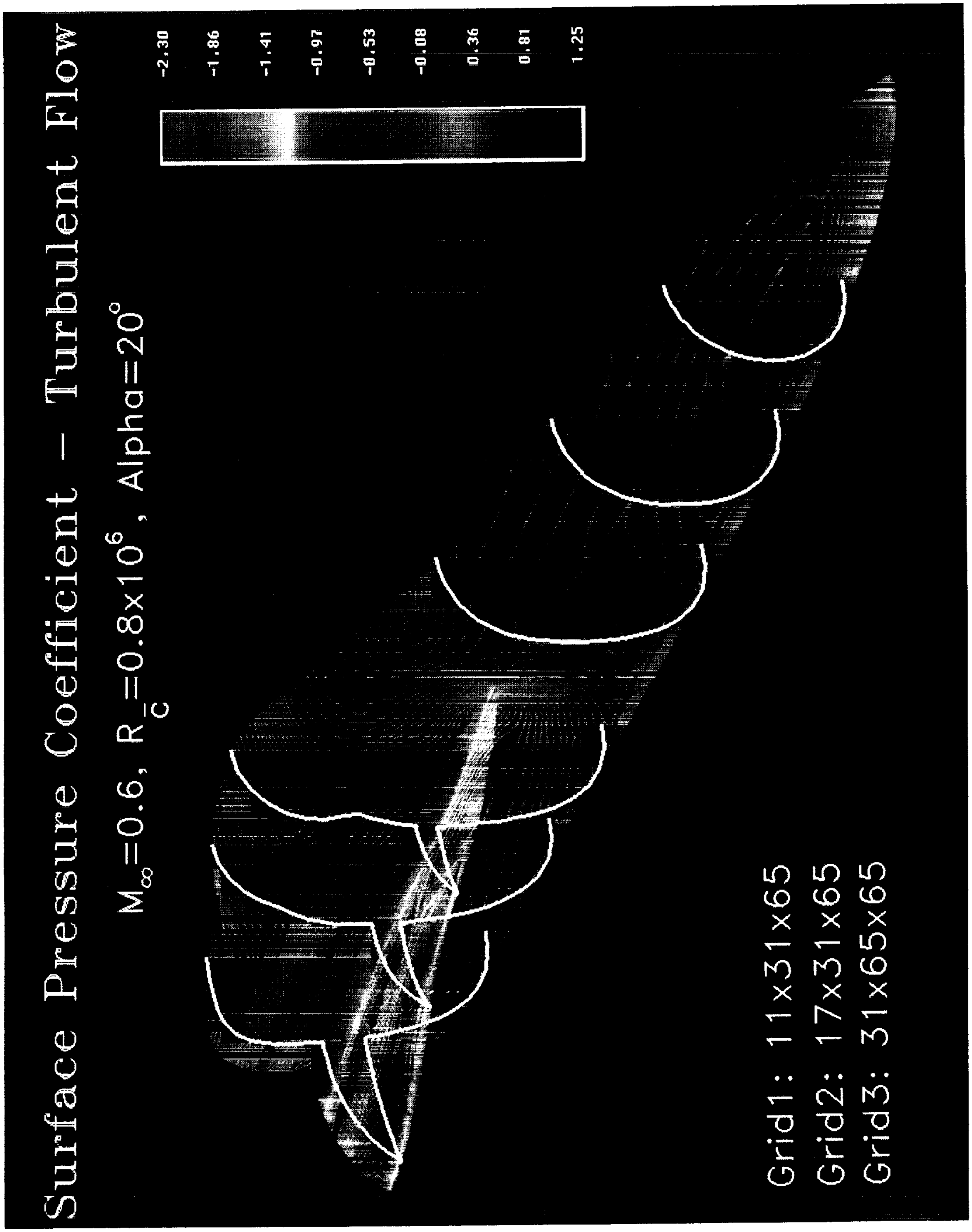


Grid1: 11x31x65

Grid2: 17x31x65

Grid3: 31x65x65

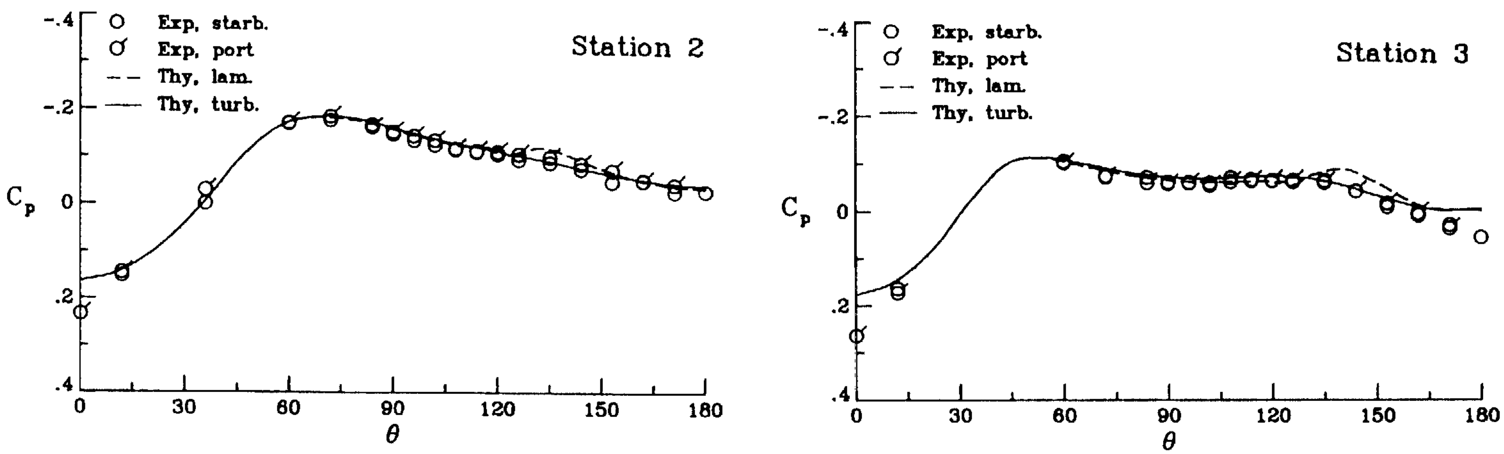

Surface Pressure Coefficient - Laminar Flow
M_∞=0.6, $R_{\bar{c}}$=0.8x10^6, Alpha=20°
-2.30
-1.86
-1.41
-0.97
-0.53
-0.08
0.36
0.81
1.25
Grid1: 27x31x65
Grid2: 31x65x65



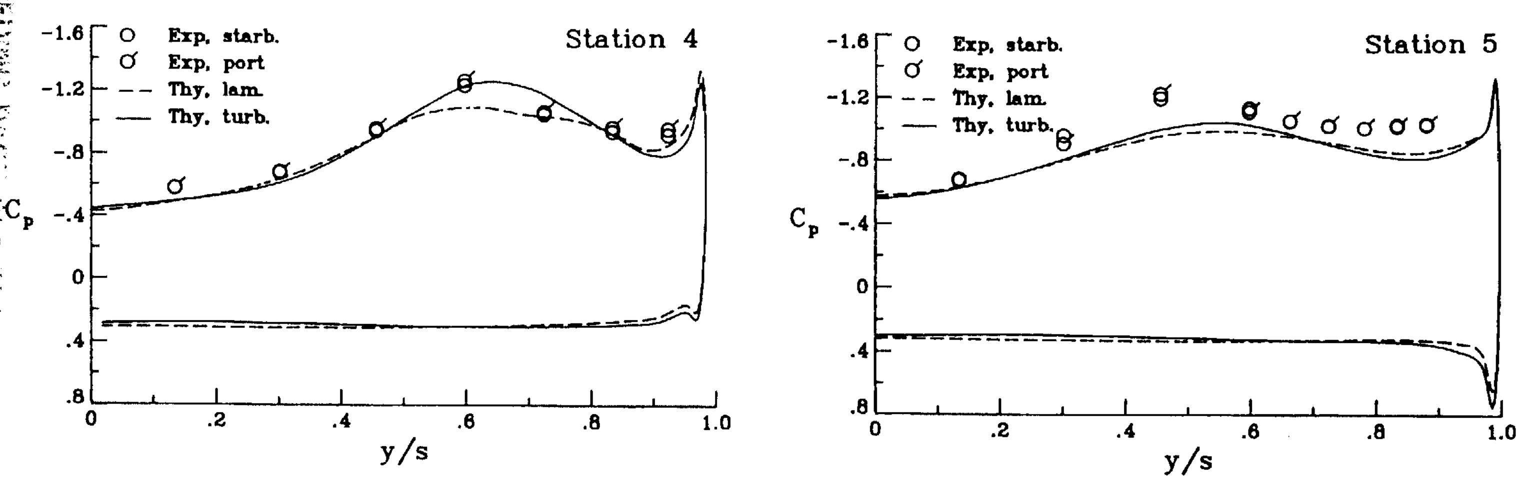
Surface Pressure Coefficient – Turbulent Flow
M_∞=0.6, $R_{\bar{c}}$=0.8x10^6, Alpha=20°
-2.30
-1.86
-1.41
-0.97
-0.53
-0.08
0.36
0.81
1.25
Grid1: 11x31x65
Grid2: 17x31x65
Grid3: 31x65x65

Forebody Surface Pressure

$M_\infty = 0.6$, $R_{\bar{c}} = 0.8 \times 10^6$, $\alpha = 20°$



LEX Surface Pressure



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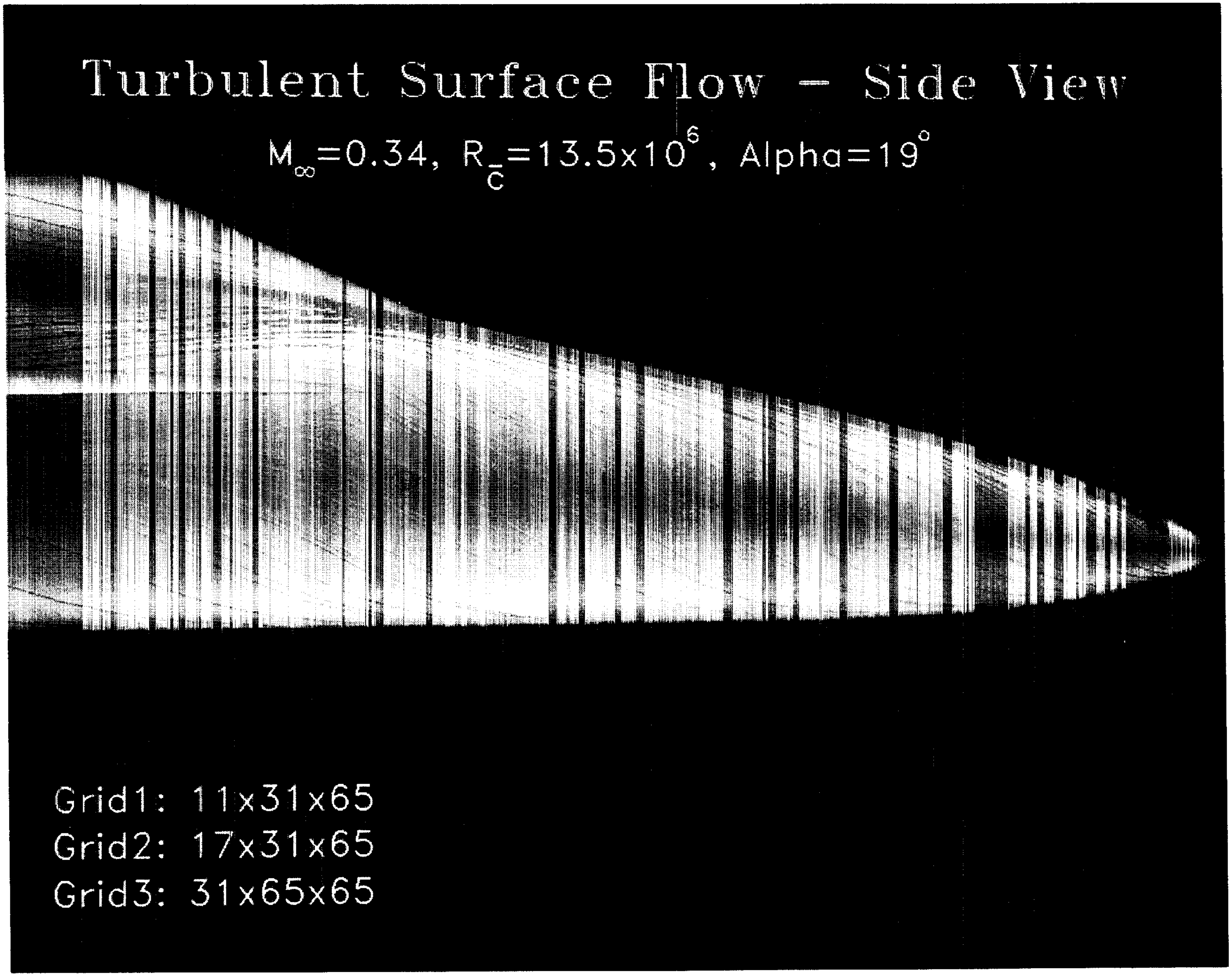
Turbulent Surface Flow – Side View
$M_\infty=0.34$, $R_{\bar{c}}=13.5\times10^6$, Alpha=19°
Grid1: 11x31x65
Grid2: 17x31x65
Grid3: 31x65x65

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Summary of Results

- Significant differences between laminar and turbulent solutions
  - Forebody
  - LEX upper surface
  - Body-LEX juncture on lower surface

- Turbulent solutions provide good correlation with experiment
  - Surface C_p comparison with wind tunnel data
  - Surface flow comparison with flight test data

- Convergence achieved with practical resource utilization
  - $\approx$ 185,000 points
  - $\approx$ 2400 cycles
  - $\approx$ 2 hours of Cray-2 time